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STATE OF OHIO
MICHAEL V. DISALLE, Governor
DEPARTMENT OF NATURAL RESOURCES
HERBERT B. EAGON, Director
DIVISION OF GEOLOGICAL SURVEY
RALPH J. BERNHAGEN, Chief

INFORMATION CIRCULAR
No. 23

Contributions To The OIL And GAS INDUSTRY In Ohio

A COLLECTION OF PAPERS
PRESENTED AT THE THIRD WINTER MEETING OF THE
OHIO OIL AND GAS ASSOCIATION IN COLUMBUS, OHIO
FEBRUARY 20, 1959

COLUMBUS
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CONTENTS

ILLUSTRATIONS

DEEP POSSIBILITIES IN OHIO

by

George G. Shearrow

During the last three years considerable interest in the lower sediments has been shown by the petroleum industry. The Sun Oil Company in 1955 drilled two basement tests in Miami and Shelby Counties. In 1956 the Gump Oil Company completed one in Shelby County. In 1957 Fayette County had two exploratory holes drilled to the basement by the Kewanee Oil Company. This year five basement tests were completed. Kewanee drilled another in Fayette, one in Clinton, and one in Pickaway. National Associated Petroleum drilled one in Maimi County and the Wiser Oil Company, et al. moved northeast to Medina County and drilled a 7,000-foot hole.

Of the 275 deep wells, those which penetrate the sediments below Middle Ordovician, only 23 have gone to the basement complex. Production has been discovered in several wells at Tiffin and Caledonia and has been recorded in several other isolated wells.

Limited stratigraphic studies indicate porosity and permeability exists in the sediments. Source rocks probably exist to the south and southeast in the basins.

Major geologic provinces surrounding Ohio had a great influence on the Paleozoic sequence. Structural features, controlling the accumulation of gas and oil were different when the sediments were laid down than they are today.

The Lower Ordovician and Upper Cambrian sediments bear characteristics of both the sediments of the Appalachian Basin and the Upper Mississippi Valley rocks but are more closely related to the latter. The Upper Cambrian rocks occur in the subsurface over the entire state but Lower Ordovician rocks are found only in the southern and southeastern parts of Ohio.

To the east and southeast is the Appalachian Basin. The presently high area of eastern Indiana during Upper Cambrian and Lower Ordovician time was a shallow basin or shelf area. The high shield area of Canada influenced the sediments and was the primary source area for the clastics which dominate these early rocks.

To reconstruct this early picture, the high shield area extended southward under Lake Erie, plunging into the Appalachian Basin and the shallow basin of Indiana. These two depressions were connected across Ohio by shallow waters. Deeper waters were found in southern Ohio and Kentucky. The Upper Mississippi Valley area and Appalachian Basin were connected through Ohio during Upper Cambrian and Lower Ordovician times.

Through these times the weight from eroded sediments being deposited further depressed these low areas and caused the north central Ohio area to gradually rise. During Lower Ordovician north central Ohio was a higher elevation than the surrounding area jetting southward into the vast embayment connecting the Upper Mississippi Valley and the Appalachian Basin.

The present Cincinnati and Findlay highs were post Lower Ordovician. It is quite probable that the Findlay high represents a westward migration of the north central Ohio high area at earlier times. Additional downward pressures on the Appalachian Basin would cause this peninsula to move westward. Soon after in geologic time the Cincinnati high was formed.

The isopachus from the base of the Glenwood to the top of the Eau Claire as well as the isopachus from the base of the Glenwood to the top of the "Granite Wash" substantiate this

*Mr. Shearrow is associated with the Ohio Division of Geological Survey.

hypothesis. The increased thickening of the sediments from north central Ohio southeastward, south and southwestward are noted on the two isopachus maps.

The structure on the top of the Eau Claire and top of the "Granite Wash" are very similar to each other and resemble the Trenton structure map compiled by Stout, Lamborn, et al., in 1932.

The Upper Cambrian overlying the "Basement Complex" in Ohio consists of sandstones, dolomitic sandstones, sandy dolomites, dolomites, and shales. In ascending order the formations of the Upper Cambrian are the Mt. Simon sandstone, the Eau Claire sandy dolomite capped by shale, the Franconia dolomitic sandstone, and the Trempealeau sandy dolomite.

The Mt. Simon ranges in thickness from 100 to possibly as much as 450 feet. The interval is controlled by the depth of the basins plus the irregular erosional surface of the underlying "basement rocks." The texture of the sand is fine to coarse, locally conglomeratic and subangular to rounded and frosted. The coarser materials being found to the north and northwest with the finer sands deposited to the south. Basinward this sandstone is quite dolomitic. Bonding materials are silica and dolomite.

The Eau Claire ranges in thickness from 400 to 700 feet. The character of this formation covers a multitude of lithologies. The brown to gray shale found at the top is poorly developed in northern Ohio but thickens to 150 feet in the southern part of the state. This widespread shale is a good marker for the driller and geologist. The balance of the formation is a dolomitic, very fine to fine-grained sandstone in the north with the sands decreasing in percentage basinward, gradually changing into a buff to brown crystalline dolomite, nearly free of clastics.

The Franconia sandstone ranges in thickness from 40 to 150 feet. The texture is fine- to medium-grained, subangular to rounded and frosted. South and southeasterly increasing amounts of dolomite are present.

The Trempealeau, youngest formation of the Upper Cambrian, ranges in thickness from 250 to 600 feet. This buff and in part white to gray finely crystalline dolomite contains minor amounts of sand, usually less than 25 percent. Thin sandstone lenses are found locally but not persistent enough for correlation.

In the northern part of the state where the Lower Ordovician is missing, the Trempealeau is overlain by the Black River and Glenwood formations of Middle Ordovician. South of the Lower Ordovician pinch-out sediments of the Lower Ordovician or Prairie Du Chien group gradually thicken and attain a thickness of 1,000 feet at the southeastern edge of Ohio.

The Prairie Du Chien group is composed of three formations. In ascending order they are the Oneota dolomite, the New Richmond sandstone, and the Shakopee dolomite. Detailed lithologies and thicknesses can not be given at this time since so few wells have penetrated the entire Prairie Du Chien group. Chert, silicified oolites, sand, and minor amounts of shale and glauconite have been noted in these sediments.

Directly overlying the Prairie Du Chien in the Upper Mississippi Valley is the St. Peter sandstone. Although "St. Peter" has been reported by most of the drillers in the deep wells, the writer has found St. Peter sand in 6 of the 275 wells that have been drilled to the Lower Ordovician or Upper Cambrian. A common error on the part of the driller is to call a crystalline dolomite a sandstone. It is probable that since the individual grains drill free they are most often identified as quartz grains. It is often possible, too, that the St. Peter sand will be found in pockets on the erosional surface most anywhere in Ohio. Generally with the St. Peter wanting, a few floating sand grains are noted in the Glenwood shale.

Deep wells drilled in the state have been confined principally to the arch areas. With 275 wells that have penetrated the Lower Ordovician and Upper Cambrian sediments and only 23 wells reaching the basement, further exploration is definitely needed.

To date two pools have been found and several other isolated wells have produced oil or gas. The Tiffin pool, located in Seneca County, was discovered about 1910. Initial production ranged from a few barrels to as much as 500 barrels daily.

In 1919 the Caledonia pool in Marion County was discovered. Initial production ranged upward to 700 barrels.

At the Newark Fairgrounds in Licking County, oil was discovered in 1924. The Wehrle Gas Company reported this well had an initial production of 150 barrels and 250,000 cubic feet of gas.

The producing horizon in the two pool areas and in the Newark Fairgrounds well was the erosional zone of the top of the Trempealeau rocks, beneath the Glenwood shale.

In the Tiffin pool the Crum well #1 was completed in 1938 with an initial production of 120 barrels. In the first eight months 6,200 barrels of oil were produced. The average annual production after the first year was approximately 1,500 barrels. In 1948, when production figures were last recorded by the Sun Oil Company, the well made 1,526 barrels, making a cumulative total of 21,284 barrels.

The Wehrle well located at the Newark Fairgrounds had an initial production of 250,000 cubic feet of gas and 150 barrels of oil. In the peak production year in 1925, 7,300 barrels of oil were produced. For the next ten years the average annual production was approximately 1,200 barrels. This well, according to the Clinton Oil Company, produced until June of 1958, when mechanical difficulties necessitated plugging. The cumulative production was 31,795 barrels.

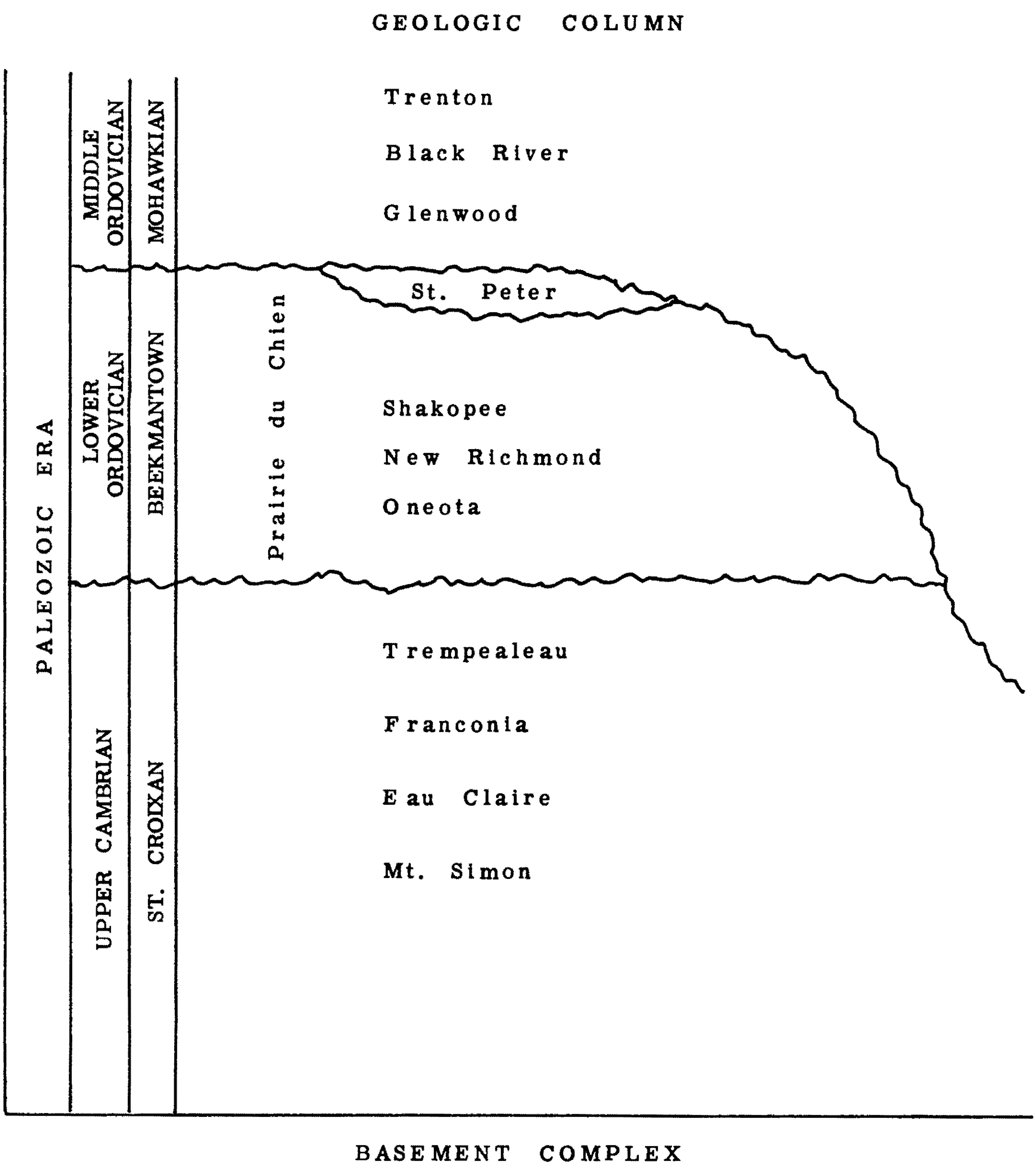
Although these figures are not phenomenal, they do give some encouragement.

From the scant sample data available it is noted that suitable reservoir conditions exist in these older sediments in the Mt. Simon, Eau Claire, Franconia, Trempealeau, Oneota, and Shakopee formations. Although drillers' records are available on the old wells and a few good strings of samples are on file, additional information is needed to determine structural and stratigraphic conditions which control the entrapment of oil and gas.

Many of the drillers' records were extremely poor as are many of todays. The drillers in some cases make little effort to record and preserve what is seen. Many are reluctant to save samples because they feel that they know all there is to be known about the rock. This may be true but there are others interested. Samples taken carelessly are worse than not taking any at all. Small samples also have a limited use since considerable amounts are needed to run all laboratory and microscopic examinations.

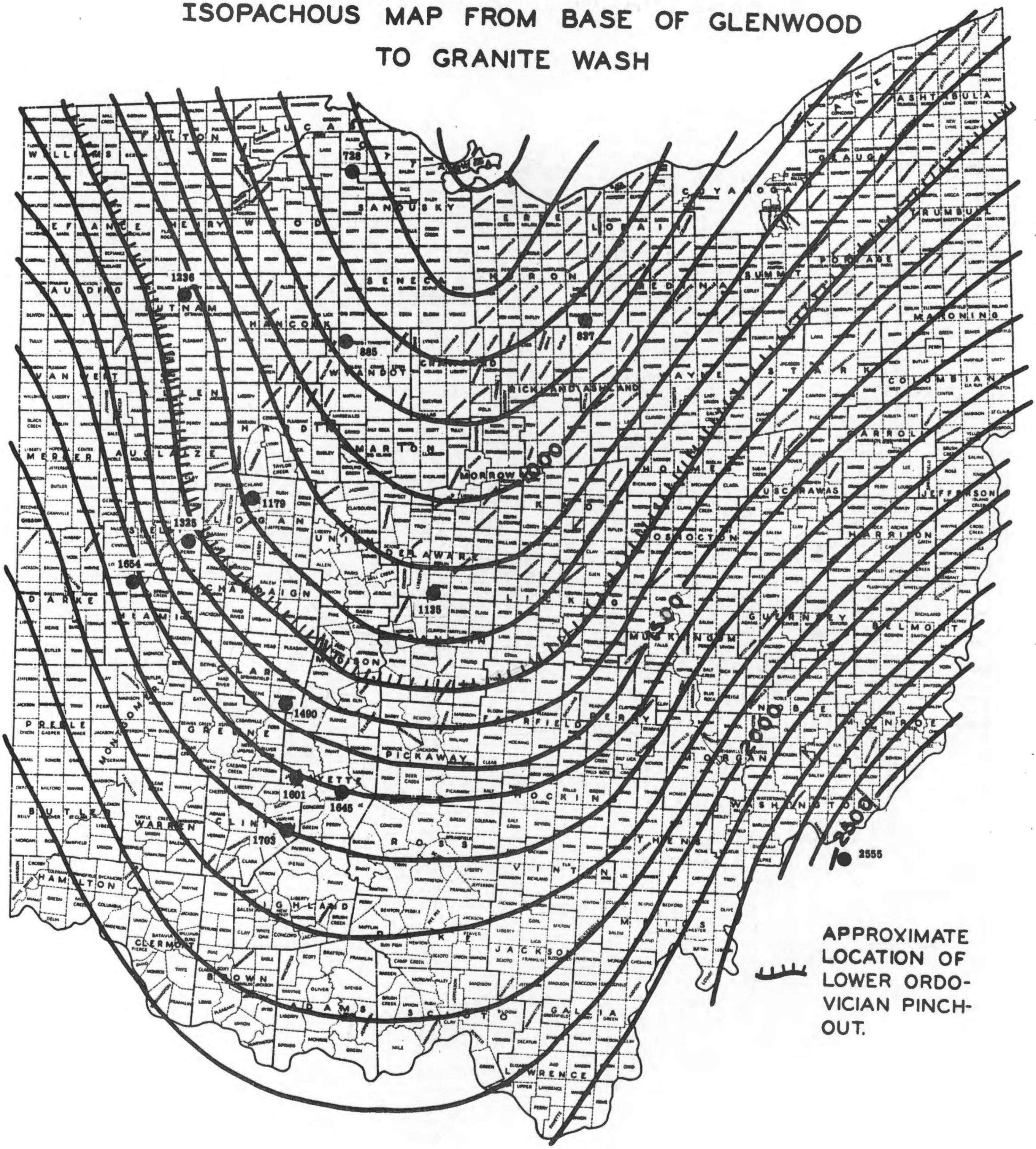
Cores, which are few and far between, are graciously accepted by the Survey. Here, again, much of the core is lost by poor packaging and some important sections are used as desk weights, watch fobs, and so forth, and lost before geologic investigations are completed.

In order to increase our reserves by locating new discoveries, research is needed. All materials, logs, and other data must be saved. The Geological Survey is your research agency and can be used to a much better advantage. Visit your Survey and support it.

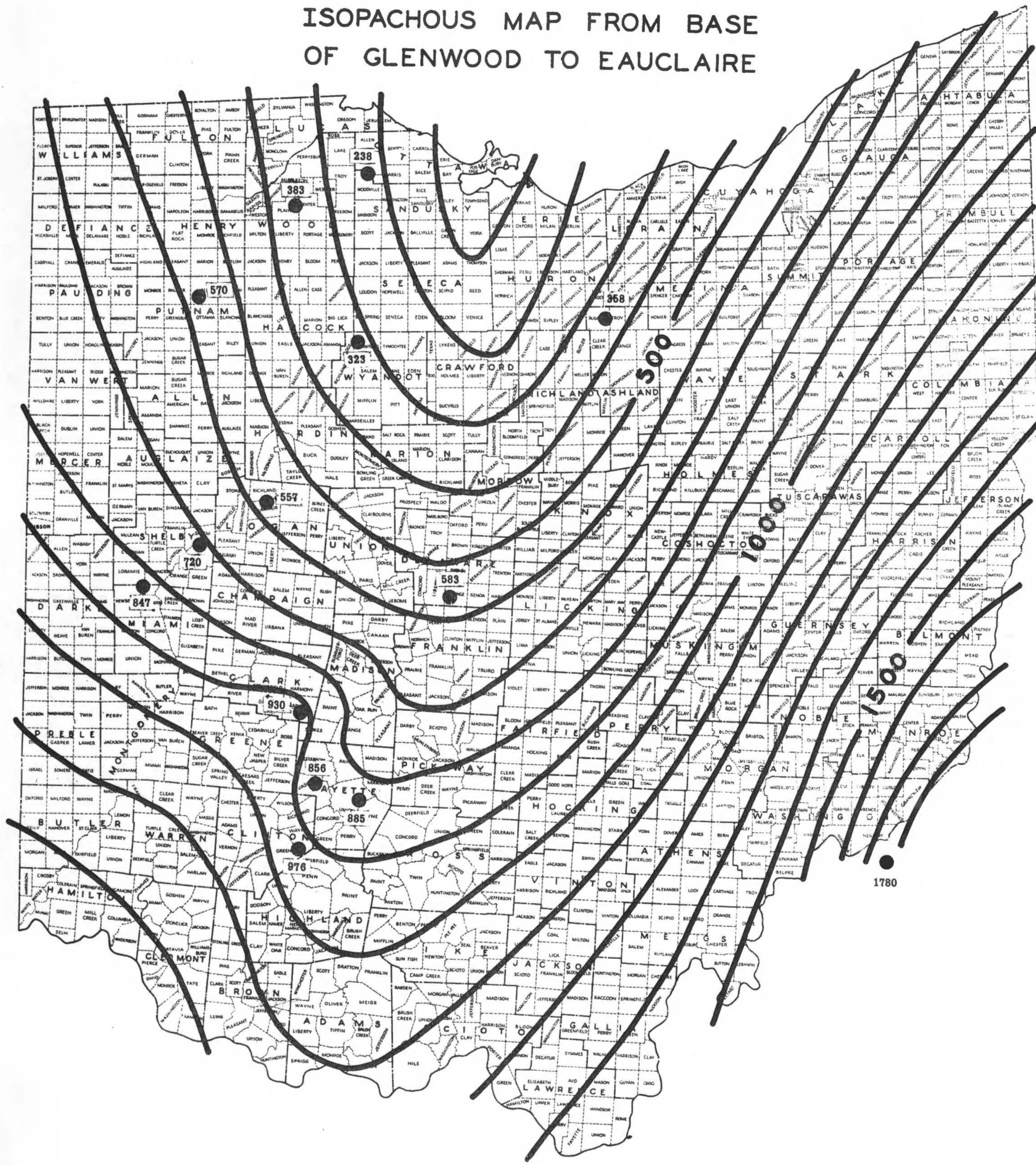

GEOLOGIC COLUMN
PALEOZOIC ERA
MIDDLE ORDOVICIAN
MOHAWKIAN
Trenton
Black River
Glenwood
St. Peter
LOWER ORDOVICIAN
BEEKMANTOWN
Prairie du Chien
Shakopee
New Richmond
Oneota
UPPER CAMBRIAN
ST. CROIXAN
Trempealeau
Franconia
Eau Claire
Mt. Simon
BASEMENT COMPLEX

WELLS PENETRATING THE BASEMENT COMPLEX

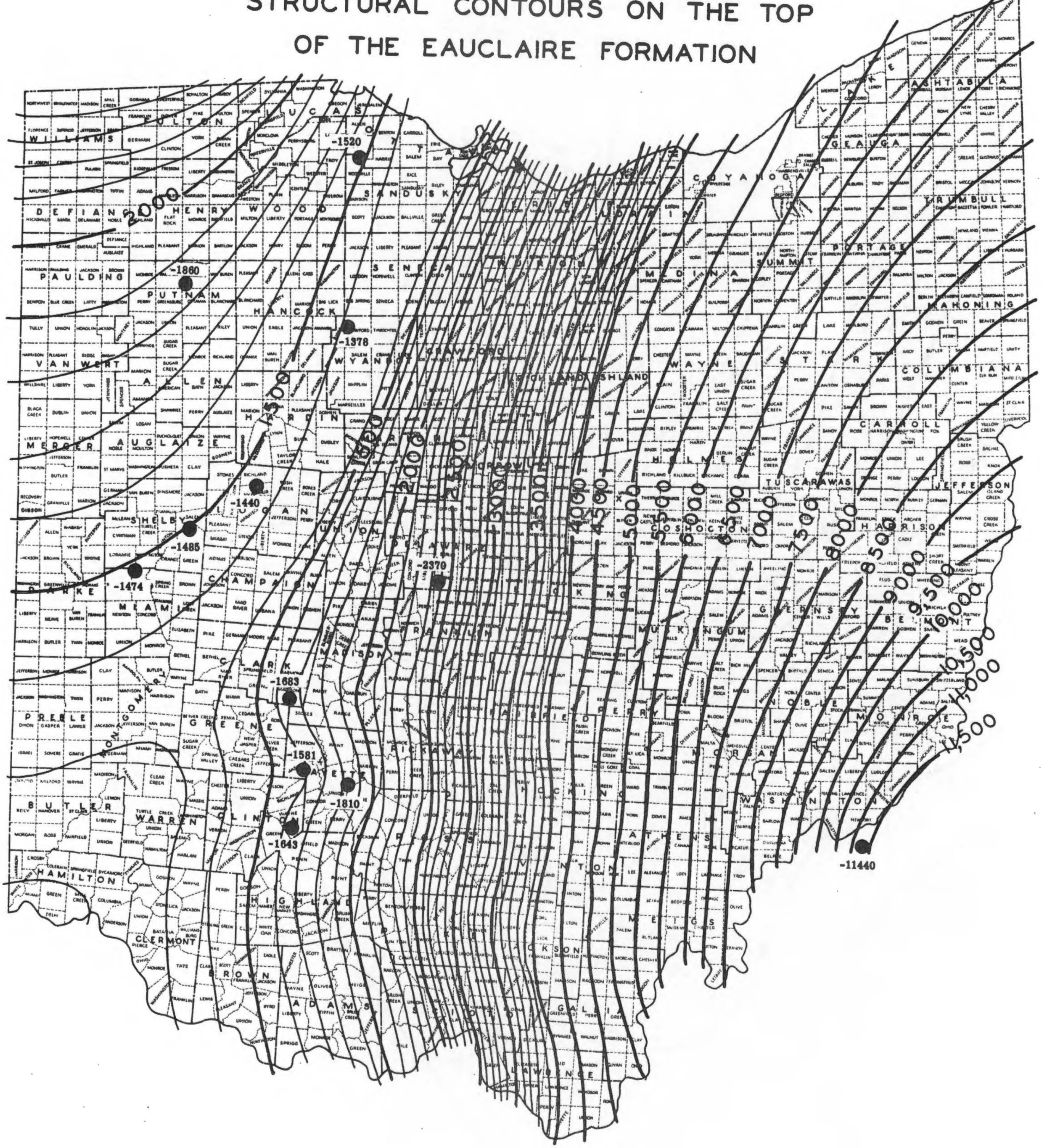
ISOPACHOUS MAP FROM BASE OF GLENWOOD TO GRANITE WASH



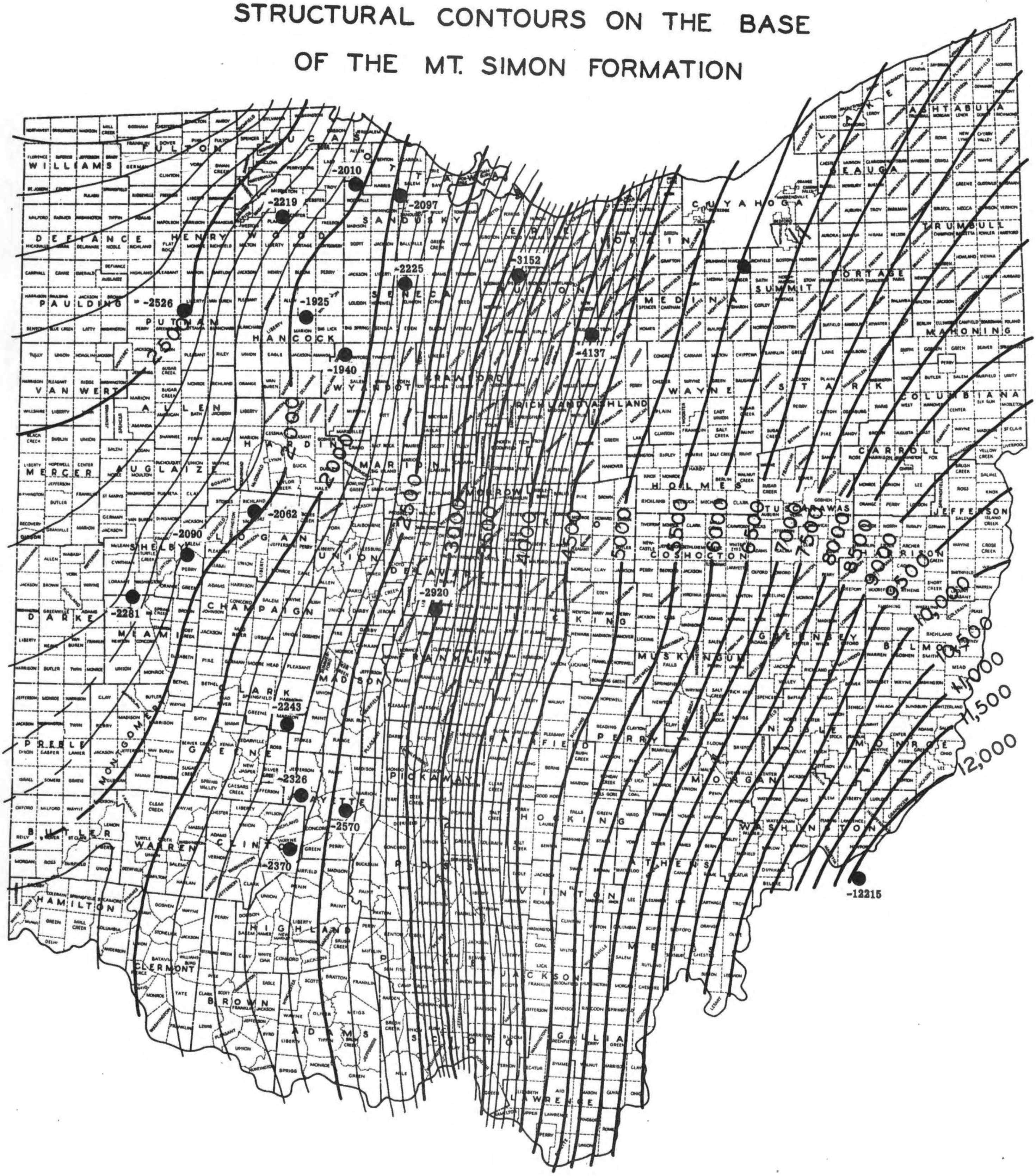
ISOPACHOUS MAP FROM BASE OF GLENWOOD TO EAUCLAIRE



STRUCTURAL CONTOURS ON THE TOP OF THE EAUCLAIRE FORMATION



STRUCTURAL CONTOURS ON THE BASE OF THE MT. SIMON FORMATION



SERVICES AVAILABLE AT THE OHIO GEOLOGICAL SURVEY

by

George G. Shearrow*

When the Ohio Legislature met in 1803, one hundred and fifty-five years ago, one of its first acts concerned a mineral resource of the State. It established regulations for the operation of the salt industry, at that time a monopoly since the State owned all of the salt springs, or licks.

During the next 33 years more and more interest was shown in the local mineral resources and geology and in 1835 Governor Robert Lucas in his annual message to the Legislature officially suggested the establishment of a State Geological Survey. As a result, a committee was appointed and in accordance with its recommendations the next legislature, in March 1837, passed an act establishing the Ohio Geological Survey. Professor W. W. Mather was appointed State Geologist and with a five-man staff started to work. A report was furnished to the Governor in December 1837 and issued early in 1838 as "First Annual Report of the Geological Survey of the State of Ohio." Work continued and a second report was made in December 1838. Because of the general financial condition of the state, appropriations for the work were not renewed and the Geological Survey was discontinued at the end of 1838.

It was not until 1869, thirty-one years later, that popular demand for mineral resource and geological information became so great that a Second Geological Survey was set up by the legislature. The second State Geologist was Professor J. S. Newberry who also retained his position as Professor of Geology in the School of Mines of Columbia College in New York City. During the next ten years the results of the studies by the members of the Survey appeared in a number of thick volumes. After a brief suspension of activity the Second Survey again received legislative support in 1882 and Professor Edward Orton took charge as the third State Geologist. The work was carried on intermittently for the next six years and several additional reports printed, emphasizing particularly the new discoveries of oil and gas.

In 1889 the Third Geological Survey was established on the basis of continuing work; although on a rather small scale. Dr. Orton was in charge of this work, too, but illness prevented his active participation and although he retained the title of State Geologist, it was largely an honorary gesture and no appropriations were made.

After Dr. Orton's death in 1899 his son, Edward Orton, Jr., was appointed the fourth State Geologist. He started the Fourth Survey in 1900 and it has been in continuous operation ever since. Dr. J. A. Bownocker became the fifth State Geologist in 1906 upon the resignation of Edward Orton, Jr. Dr. Bownocker was professor of geology at The Ohio State University and was thus only able to devote summers and spare time to Survey work. In 1921, when the state government was "departmentalized," the Survey became a division of the Department of Education. Upon his death in 1928, the work of the Survey was separated from the university work and Dr. Wilber Stout became the sixth State Geologist and the first one to devote full time to the work. In 1943 the Survey was transferred to the Department of Public Works.

Dr. Stout retired in 1946 and Dr. George White was appointed the seventh State Geologist. After 15 months of invaluable service to the state, Dr. White was made Chairman of the Geology Department at the University of Illinois and the eighth man to hold the position in 110 years, John H. Melvin, was appointed State Geologist.

Two years later, in 1949, with the passage of Senate Bill 13, the Geological Survey became one of the seven divisions of the new Department of Natural Resources.

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*Mr. Shearrow is associated with the Ohio Division of Geological Survey.

Following John H. Melvin's resignation to accept a position with industry, Ralph J. Bernhagen was appointed the ninth State Geologist on January 1, 1957.

When the Survey started its work few minerals were produced in Ohio, the value of oil and gas was unknown and our vast chemical industries based on limestone and salt were undreamed of. Today, however, Ohio is a leading mineral-producing state and because of these basic raw materials we rank second among the manufacturing states. No area of equal size on the face of the earth is so productive.

The present physical makeup of the Survey consists of four principle sections.

The Coal Section involves both applied and fundamental research to evaluate the coal resources economically and geologically.

The Areal Geology Section maps the surface rock and mineral units on county-wide or other designated areas.

The Industrial Mineral Section investigates the economic aspects of the occurrence of all minerals other than coal, oil and gas.

The Subsurface Section is responsible for the collecting, studying, and interpretation of geological material pertaining to the rocks and minerals found below the surface of the gound and publishing and distributing the results of the studies conducted.

The greatest source of subsurface information is obtained from the study of holes drilled for the exploration of minerals. Annually more than 1,200 tests are drilled in Ohio for the purpose of locating limestone, dolomite, salt, natural brine, oil and gas. Wells, for the production of oil and gas, account for 95 percent of the information obtained by the Surburface Section.

Since the oil and gas well records are the most important source of data for the Section, there is close cooperation with the oil and gas industry. This Section has become a depository and distribution center for drilling and production data and as a result the servicing of requests for information has dominated its activities. Every effort is made to have available the type of maps and data required by the oil and gas industry.

Last year eight counties in the eastern part of Ohio were posted with well locations obtained from all available sources. The maps are posted with new permits, plugging permits, and completion data obtained from the Division of Mines and the Ohio Oil and Gas Association. Approximately 3,000 permits and completions were posted to keep up with current drilling activities. In addition and in conjunction with the map work, the same number of drillers' logs were processed, typed, and filed.

Two hundred electrical, gamma-ray, and neutron logs were collected and 5,509 drill cutting samples representing 55,233 feet of hole were collected and preserved. The drill samples collected represent less than 3 percent of the footage drilled. Additional samples would be collected and studied if funds and personnel were available. The information obtained from the studies of additional material could lead to the discovery of additional mineral reserves and better conservation practices.

During this year 712 visitors used the subsurface log, map, and sample files. The estimated number of logs copied is over 100,000 and 3,786 well location maps were reproduced.

The following speeches and papers were given during 1957 by the writer:

A paper entitled "The Insoluble Residue Study of the Wood County Deep Well" was presented before the Appalachian Geological Society at Black Water Falls State Park, West Virginia.

A paper entitled "Oil and Gas in 1957" was presented before the Ohio Academy of Science.

TABLE 1 *

MINERAL PRODUCTION IN OHIO, 1956-1957 [a]

Mineral	1956		Preliminary 1957	
	Short Tons (Unless otherwise stated)	Value	Short Tons (Unless otherwise stated)	Value
Cement:				
Portland, (376-pound barrels)	15, 150, 874	$ 46, 341, 562	15, 733, 000	$ 49, 874, 000
Masonry, (376-pound barrels)	914, 371	3, 451, 959	856, 000	3, 356, 000
Clay.	6, 702, 531	17, 675, 504	5, 870, 000	17, 300, 000
Coal.	38, 933, 557[b]	148, 650, 186[b]	36, 420, 000	(c)
Lime	2, 995, 320	40, 804, 580	3, 147, 000	40, 376, 000
Natural gas, (million cubic feet)	25, 368	6, 088, 320	26, 500	6, 492, 000
Peat	15, 509	174, 469	(c)	(c)
Petroleum (crude) thousand 42-gallon barrels	4, 785	15, 024, 000	5, 447	18, 520, 000
Salt (common)	2, 971, 702	15, 922, 765	2, 735, 000	14, 330, 000
Sand and gravel	30, 199, 822	36, 146, 175	27, 500, 000	32, 600, 000
Stone	33, 417, 662[d]	50, 946, 715[d]	34, 100, 000[d]	51, 200, 000[d]
Value of items that cannot be disclosed: abrasive stones, gypsum, natural gasoline, natural salines, crushed sandstone, recovered sulfur, and minerals whose values must be concealed for particular years indicated in appropriate column by footnote (c)		5, 393, 583		151, 682, 600
Total Ohio		$ 375, 487, 000[e]		$374, 042, 000[e]

a - Production as measured by mine shipments, sales or marketable production (including consumption by producers).
b - Preliminary figure, subject to revision.
c - Figure withheld to avoid disclosure of individual company confidential data.
d - Incomplete total.
e - Totals have been adjusted to avoid duplication of value of limestone for cement and lime which are included in the value of cement and lime.

* Table from U. S. Dept. of Interior, Bureau of Mines, Mineral Industry Surveys, Area Report H-90 (January 7, 1958), Table 1.

Report of Investigation No. 35, "1957 Oil and Gas Developments in Ohio."
"Salt a Luxury," Ohio Conservation Bulletin.
"Completions Falter, But Ohio Production is Boosted," Oil and Gas Journal.
"Oil and Gas Well Drilling Highlights," Ohio Conservation Bulletin.
"Summary of Oil and Gas Well Drilling Activities in Ohio During 1956," Annual Coal and Non-Metallic Mineral Report.
A speech concerning the mineral resources of Ashtabula County was given at the annual meeting of the Ashtabula County Soil Conservation District.

The writer was appointed to the following committees:

1. Ohio Oil and Gas Association's Ethical Practices Committee.
2. American Association of Petroleum Geologists' Stratigraphic Correlations Committee for Eastern United States.

Projects for the future will be the continuation of the compiling of property maps with well locations shown, collecting and posting current well data, collecting of well sample cuttings and cores.

Proposed future reports are the Annual Oil and Gas Statistics; Revision of the Oil and Gas Fields Map in 1960; a study of the Moorland Field; and two geologic cross sections, one east-west section along Lake Erie and a north-south section from Marietta to Ashtabula.

The above projects are only a small part of the work. Actually, industrial visitation and correspondence account for over 75 percent of the time of the employees in the subsurface section.

Until now, Survey appropriations have not been mentioned, however, this evil is a necessity. The total funds available for 1957 were approximately $164,000, of which $134,000 was ear-marked for salaries. This figure is 0.6 percent of the value of oil and gas produced in the state or 0.04 percent of the value of all minerals produced.

Ohio, which ranks 16th in order of size of annual appropriations to state geological surveys, has smaller appropriations than three of the surrounding states. Pennsylvania has $441,000; Michigan $413,000; Indiana $392,000 for annual appropriations. Kentucky, which is 29th, has just completed a $7,000,000 topographic mapping program and has indicated its intention to establish a modern geological survey with the recent appointment of a new State Geologist. It is quite obvious where Ohio stands in relation to its neighboring states.

If Ohio is to keep abreast of its rapid industrial expansion and continues the services now offered by the Survey, additional funds will be needed.

You, as representatives of industry must support the Survey in every way possible.

PRODUCTION CURVES ON FRACTURED CLINTON OIL WELLS

by
John C. Wright

The advent of hydraulic fracturing into the State of Ohio in 1951 has resulted in an increased oil production, increased number of wells drilled, and a lessening of the dry hole percentage. In the first instance it was difficult for Ohio operators to accept fracturing due to the increased completion cost and the general economics of Clinton production. However, as the results of the first treatments became known, fracturing soon was almost standard procedure as a completion practice.

Figure 1 shows the increase in number of wells drilled and the lower dry hole percentage since 1950. Also shown is the number of fracture treatments yearly since 1951.

The favorable response of the Clinton sand to fracturing may be due to several reasons. Various types of logs run have shown that what is frequently called "broken sand" is actually a series of sand stringers interlaced with shale streaks. Very frequently these sand stringers are quite thin. It is the writer's opinion that the frac fluid travels along these shale-sand interfaces or bedding planes, thereby exposing more area to drainage. The few radioactive tracers run in frac treatments have generally shown this to be the case. Where formation breakdown occurs within the sand body itself, it is felt that the frac fluid reaches out similar to a tree root pattern following the more permeable zones or paths of least resistance. The injected frac sand itself may have value both as a propping agent and also as an abrasive material.

Hydraulic fracturing has been responsible for generally better completion practices. The normal procedure prior to fracturing was to set casing through the Niagara lime in the Casing Shell or Packer Shell on a steel or lead shoe and drill the remaining 150 to 200 feet of hole. The well was then shot, cleaned out, and a perforated liner run. Some operators still follow this procedure, particularly where old pipe is used that would not stand the pressure of fracturing. Here treatment is accomplished through tubing on a packer. Today most wells are completed with casing set on the top of the Clinton sand and the pipe cemented in. Another method includes setting pipe through the Clinton and preferentially perforating the pay zones. A variation of this method is to set pipe through the top Clinton section and cement, leaving the bottom Clinton section completed in the open hole. These variations in completion practice have brought in the stage treatment using temporary plugging agents and perf balls.

Figure 2 shows the trends in fracture treatments from 1951 through 1958. They have been furnished by one of the service companies involved in treating wells in our area. An increasing trend can be seen in total volume of fluid, sand-laden fluid, and sand volumes used. The average horsepower and injection rate per job have been climbing rapidly since 1956. The average sand concentration in pounds per gallon has remained fairly steady since 1955, being 1.10 pounds per gallon in 1958. The percentage of gelled oil treatments has shown a decided decline since 1955. All of the first treatments in 1951 and 1952 were hydrafrac treatments.

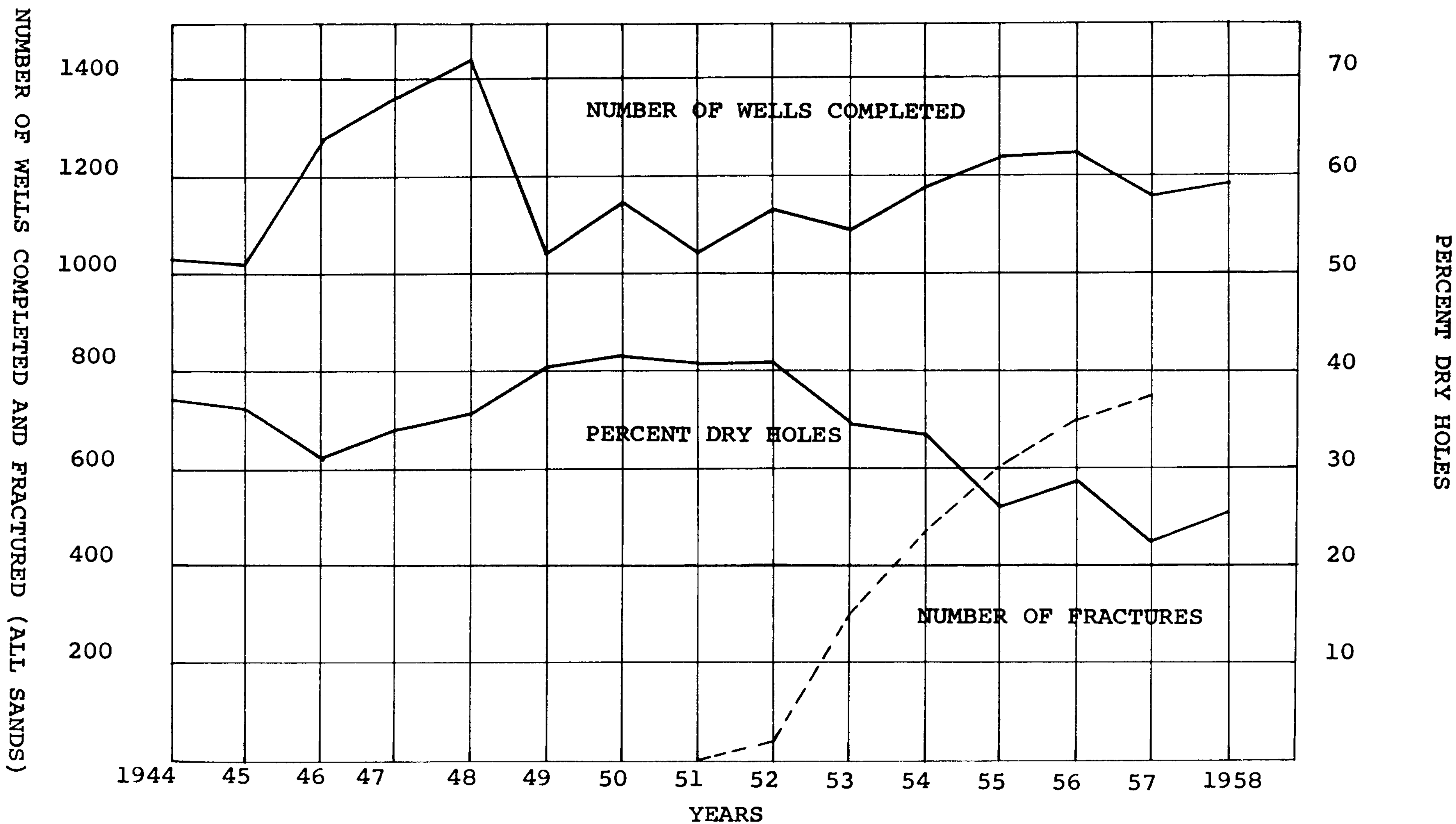
The data in this analysis involves 39 wells. These wells are located in the following counties: Coshocton, Hocking, Holmes, Knox, Licking, Medina, Muskingum, Perry, and Wayne. It might be added that no information from the Moorland pool in Wayne County is included. Data is limited to one well leases. The companies involved in supplying this information keep accurate records and we can assume it to be fairly reliable, both as to initial potentials and monthly productions.

* Mr. Wright is associated with the Wiser Oil Company.

COMPLETIONS, FRACTURES AND PERCENT DRY HOLES

ALL WELLS (OHIO)

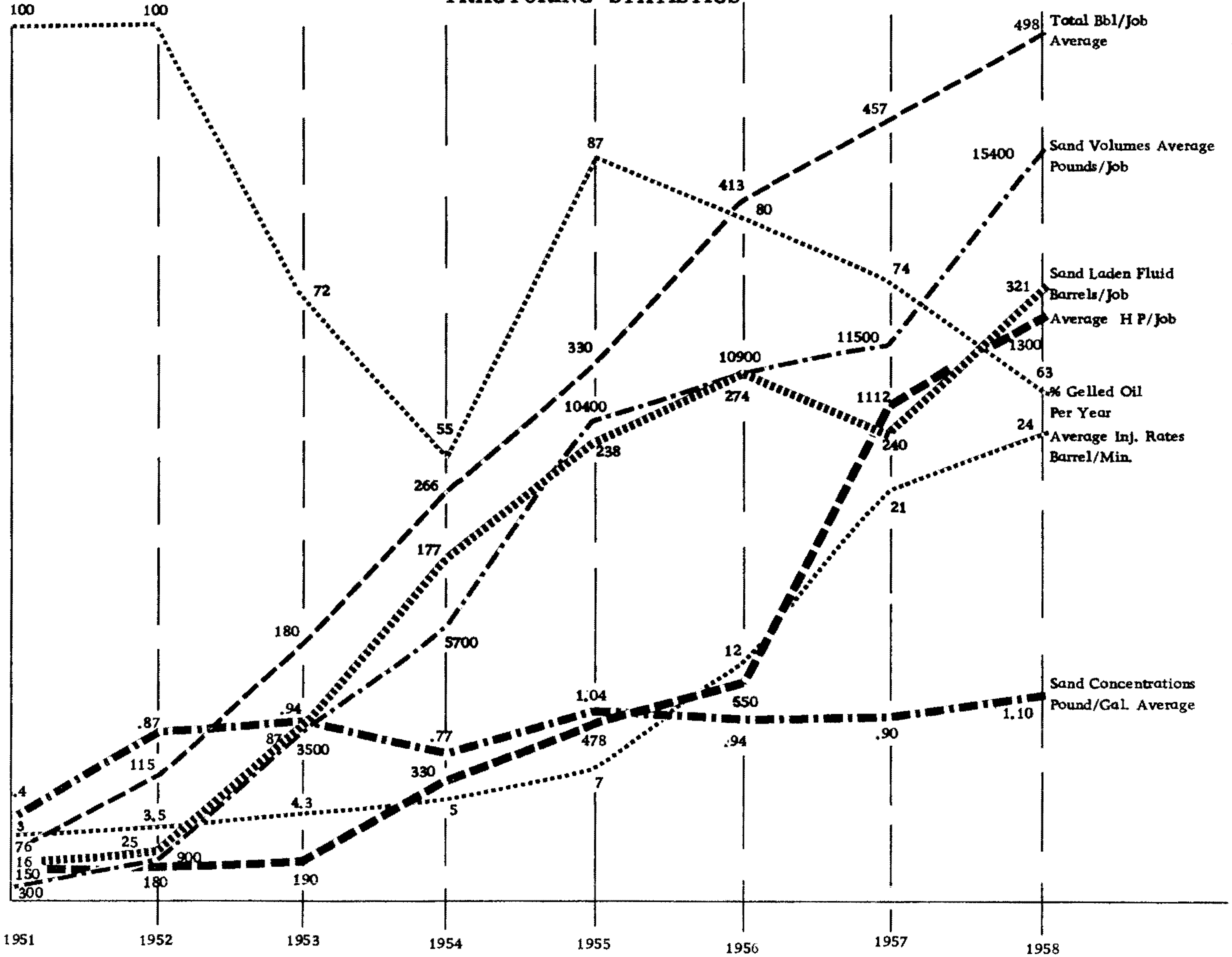
Figure 1



Source: Ohio State Geological Survey
Ohio Oil & Gas Association

Figure 2

FRACTURING STATISTICS



Source: Halliburton Oil Well Cementing Company.

Table 1 compares succeeding months production with the first month after frac in both barrels and expressed as a percentage decline. Also shown is the average initial potential after frac of the 39 wells and the ratio of the first month's production to it. You will note that production has declined 89 percent in the 36th month from the first month.

Table 2 includes data from 45 wells, including the 39 wells used above. Here production is shown in twelve-month periods with the percentage decline and the net daily production for these periods. Also shown is the average initial potential before and after frac, their ratio of increase, and the ratio of initial potential after frac to the first twelve months' production.

Figure 3 shows the plot of this data on log-log paper. It is realized that five points are ncessary for a more valid interpretation, but we must work with what we have. The straight line from these points has been extended to an assumed economic limit of 300 net barrels of oil per year or 0.8 barrel oil per day. This shows a productive life of approximately ten years. During this period this "average well" will have produced approximately 12,900 net barrels.

Now let us get into the economics of this data. The average Clinton well completed, pumping into the tanks, will require an initial investment of around $30,000. Corning grade oil at $2.72 per barrel is most representative of the production from this group of wells. To return the initial investment at this per barrel price will require the recovery and sale of approximately 11,000 barrels.

Using the slope of line established in figure 3 and the ratio of initial potential after frac to the first twelve months to establish a starting point, we find it will take at least a 150 barrel initial potential after frac to merely return the initial investment. Of course, this does not take into account the cost of lifting the oil or other fixed expenses. Therefore, a well should range upward from an initial of 200 barrels of oil after frac (16,000 barrels ultimate) before a company can expect to realize any profit. This line is also shown on figure 3. Out of the 45 wells only 10 or 22 percent fell into the 200-barrel or better classification.

A casual observation of the Ohio Drilling Report will show that the above conclusions do not paint a pretty picture. A question may be raised as to whether this group of wells is representative of Clinton production in general, and the methods used to arrive at these results might be questioned. My guess is, however, that many wells fall into this general classification. A great many Clinton wells, then, are merely a "trading dollars proposition" with the only profit, if any, in recoverable salvage. Many wells in the 25 to 150 barrel range after frac will lose money. It appears then, that there is some question as to the validity of our present dry hole ratio and our big potentials after frac.

Clinton reservoirs are yielding more information as a few cores are being taken and more wells logged. A truer actual pay thickness, porosity, and percentage water saturation can be obtained, with a consequent truer reserve picture. Where enough logs are available, the trends in the thinning or thickening of the sand lenses may be observed. This can eliminate some dry holes and may somewhat change spacing considerations eventually.

The Clinton sand is a low pressure sand, the recovery mechanism being solution gas drive and gravity drainage. Conservation of reservoir energy is essential to increased ultimate recovery. Several pressure maintenance programs using gas are underway in Ohio. Too many operators do not try to conserve what gas they have and make it work for them. As the gas approaches the well bore it expands, thereby pushing oil ahead of it. This is due to the differential pressure created by the presence of the well bore. If this expansion is not somewhat inhibited the gas will come out of solution too rapidly and bypass much oil. A very fine paper was given on this subject at the meeting of the Ohio Oil and Gas Association last year.

There are an increasing number of operators using the medium of hydraulic fracturing on wells previously shot. Results generally have been reported good from an economic standpoint. Also, second fracture treatments are being attempted. The results here are inconclusive and it would be well if a study of this be made.

Figure 3

YEARLY PRODUCTION TO ABANDONMENT
(Data From Table II)

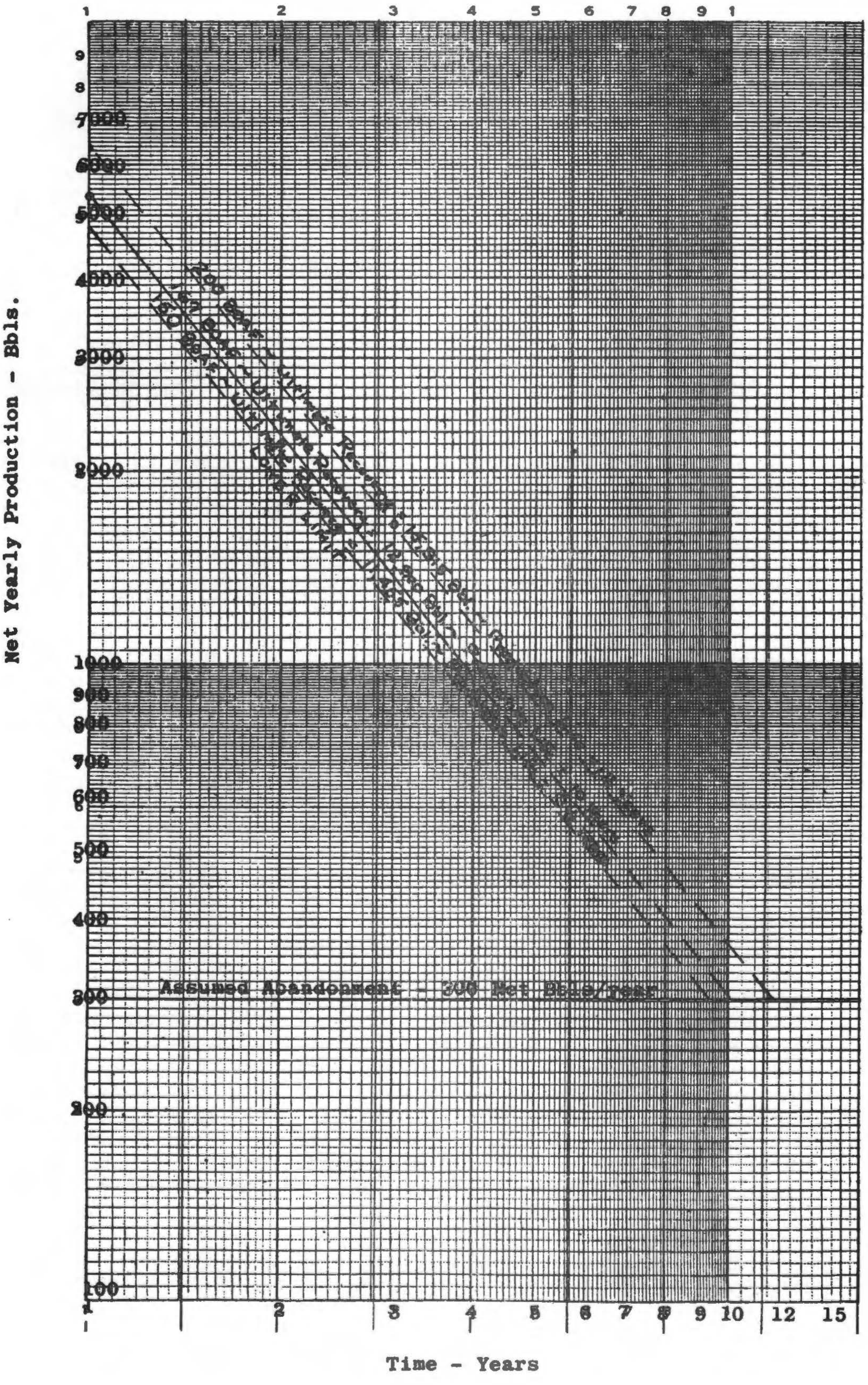


TABLE 1

AVERAGE OF 39 WELLS

Initial Potential After Frac	First Month's Production	Ratio
174 Bbls.	1,289 Bbls.	7.42 to 1

Month	Net Bbls.	Percentage Decline From First Month	Net Bbls. Per Day (30-day month)
First	1,289	-	43
Third	716	44	24
Sixth	411	68	14
Ninth	310	76	10
Twelfth	266	79	9
Eighteenth	180	86	6
Twenty-fourth	160	87.5	5
Thirty-sixth	139	89	4.6

TABLE 2

AVERAGE OF 45 WELLS

Initial Potential (Bbls.)		Ratio of Increase	Ratio of Initial Potential After Frac to First Twelve Months' Production
Natural	After Frac.		
6.85	167	24 to 1	31.9 to 1

Net Production (After Royalty) for Twelve-Month Periods

	Barrels	Percent Decline	Net Bbls. Per Day (365-day year)
First 12 months	5,335	-	14.60
Second 12 months	2,202	59	6.05
Third 12 months	1,659	25	4.54
Fourth 12 months	878	47	2.40

In conclusion, constantly rising costs and the low price received for our product make it essential that we consider our future drilling and producing programs carefully. It appears that Ohio's recent "oil boom" has been somewhat blown out of proportion and that maybe we're closer to the national dry hole average than we think.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the following companies for their cooperation in providing data: Barron Kidd, Clinton Oil Company, National Gas & Oil Corporation, Waverly Oil Works, Oxford Oil Company, The East Ohio Gas Company, and Halliburton Oil Well Cementing Company. The following individuals were most helpful in providing information: Professor E. V. O'Rourke of The Ohio State University, Mr. Ira M. Korst of the Ohio Oil & Gas Association, and Mr. George Shearrow of the Ohio Geological Survey.

CUTTING OPERATING COSTS

by

Brady Johnson*

In the wake of continued increased costs and low crude prices, slim hole equipment offers the Ohio producer a prospect of reduced completion costs in the range of four to five thousand dollars per well.

The main purpose of this paper, therefore, is to present information and a few ideas which may be helpful to your thinking and evaluation of the savings and practicability of scaling down completion and production equipment of an Ohio Clinton well.

I doubt that there are but very few present who are not greatly concerned with the subject of the ways and means of reducing costs in these inflationary times. When we look to the future in the light of past and present trends, it becomes very clear that we must begin now to think, plan, and explore every avenue with a possibility of leading us to greater economy of operations.

A recent survey of the construction and equipment costs of Clinton wells completed by a large Ohio producer reveals that, during the past five years, increases have averaged nearly eight percent per year, whereas crude prices are at practically the same level as they were ten years ago. The October issue of the Oil and Gas Journal carried an article on page 47 stating that 45 percent of the nation's production had received price cuts in 1958, resulting in $700,000 per day less income to producers. Also, in October of 1958, the Cost Study Committee of the Independent Petroleum Association of America, at its annual meeting in Dallas, Texas, presented a very comprehensive report emphasizing the serious position of the domestic oil industry relative to inadequate prices, loss of markets to foreign imports, and rising prices of materials and wages.

We cannot assume, however, that the oil industry is unaware of and doing nothing about these problems. When we examine oil trade journals, we find evidence of the technological efforts directed toward obtaining greater revenue per dollar invested. For example, the 1959 January issue of Petroleum Engineer carried an article covering new drilling and production developments in response to the demand for cost reductions. Items such as vibratory drilling, electric rigs, all hydraulic rigs, and turbodrills were mentioned as drilling advancements. In the field of production, rapid advancements in lease automation, multiple and permanent completions, and sonic pumps were reported. Secondary recovery, as a key to locked reserves, now includes projects of miscible phase displacement, in situ combustion and, most recently, underground release of nuclear explosions in the vast shale deposits of Colorado. On page B-22 the article states:

"The most significant development in well completions during recent months has been the tubingless completion method. Coupled with multiple completions, this technique promises huge savings in the amount of 'iron' used in new wells.

"Humble Oil & Refining Company has made one of the most interesting applications of the technique, in which the only large-diameter casing used was that required for surface casing. A bundle of three small (2-7/8" diameter) casing strings was clamped together, run into the hole and cemented in place."

Recently, I was very much surprised to read of Gulf Oil's circulation clean-out and rework program conducted inside of 2" tubing using 3/4" upset tubing as a fluid conductor. The result was an estimated $500,000 savings in 71 jobs.

* Mr. Johnson is associated with Natol Corporation.

These developments have been mentioned only to point out that others in the industry are actually doing something about their problems, and while recognizing the fact that the Ohio producer is limited by economics from conducting any sizeable research or experimental projects, we must be aware of and quick to apply any development or method which might cut costs of our own operations.

With these previously mentioned points in mind, in June of 1958 Natol Corporation initiated a project to consider the design and testing of scaled-down slim hole production equipment. The purpose was to first determine or answer the question, can a Clinton well be successfully produced in very small casing strings, and second, can the method and equipment be utilized with savings and, if so, how much.

The following portion of this paper will:

1. Review some of the facts and problems considered before equipment was selected.
2. Discuss the design and selection of equipment.
3. Cover the installation of the equipment.
4. Present operational results.
5. Suggest methods of completion.
6. Give an example of possible savings.
7. Discuss other miscellaneous savings, problems, advantages and disadvantages of this type completion.

SLIM HOLE TEST INSTALLATIONS

First considerations of the possible scaling-down of equipment required that recognition be given to a few facts and problems peculiar to Clinton production. First of all, during the initial four or five years, as much as 40 or 50 percent of a well's primary production may be recovered. Good Clinton wells are characterized by high initial production which then declines in a short time to settled production of a few barrels per day. An analysis of production rates shows that the capacity of presently used casing, tubing and pumping equipment is considerably oversize the greater part of their service life.

Next, assuming that very small casing was to be used, perhaps 2-7/8" tubing, questions arose as to the production problems of flowing wells, paraffin control, and pumping methods where very little reservoir and annular space between tubing and casing exists.

In the case of flowing production, it was decided that very large wells could be produced directly through the casing string and, also, that a small piston lift should be developed and tested coincident with a pumping installation.

Since no large gas separation space or reservoir would be available when pumping, the long, slow stroke of a small-bore pump operating 24 hours a day was considered most suitable.

The problems of servicing and cleaning out a slim hole completion were also considered; however, after determining the availability of tools and methods already developed for slim hole work, no unsurmountable problem was foreseen which would make it inadvisable to proceed with a test installation.

Design and Selection of Equipment

With the above considerations in mind, the following items of equipment were either purchased, modified or designed and built for this particular project.

<u>Casing and Tubing.</u> - Since the goal of the project was to achieve maximum savings, no compromise was made in selecting the minimum practical size of the casing string. After considering pumping through hollow rods, casing pumps, etc., 2-1/2" regular tubing was chosen. One and a quarter inch upset tubing was next checked as to setting depth, and running clearances in the 2-1/2" casing. It was found to be adequate for the depths encountered in Ohio and clearances were satisfactory.

The availability of 2-1/2" tubing was no problem; however, 1-1/4" upset tubing was finally acquired from a Detroit firm who sent the material to Texas for upsetting and returned it at a figure which, it is my understanding, resulted in a loss to them. However, considerable interest in the project has been shown by company representatives and upsetting equipment will be installed if suitable future market conditions develop.

<u>Pumping Equipment.</u> - Having selected the casing and tubing strings, the next major items considered were equipment to transmit power to the bottom-hole pump, the type of bottom-hole pump, and a surface pumping unit.

Rods and Wire Line: After many phone calls and letters to rod manufacturers, it was found that there were no small rods on the market at the time with a box and pin O. D. which would operate in 1-1/4" tubing. As a result, wire line dimensions and strengths were checked and a 5/8", 6 x 7 regular left lay, steel core line was selected. A left lay line was chosen because of its tendency to tighten any threaded joints in the system thus reducing the possibility of fishing jobs. The breaking strength of a 5/8" wire line is nearly 15 tons, which calculated to provide about a seven to one safety factor.

I would like to mention that, recently, the Liberty Manufacturing Company of Fort Worth, Texas, began marketing a 1/2" rod for operation in 1-1/4" tubing. This rod was originally developed for the Humble Oil & Refining Company. Bethlehem Steel is also now marketing a 1/2" rod, and I have been told that two other manufacturers will be in production in February of this year.

Bottom-Hole Pump: In regard to bottom-hole pump selection, a 1-1/16" insert barrel was adapted to the 1-1/4" tubing string. The double valve plunger of the pump was attached independently to the wire line system.

Pumping Unit: It has been mentioned previously that, due to the absence of reservoir space, a long, slow stroke was desirable. Both hydraulic and beam type units were considered, and after a review of all operating requirements, a beam unit was selected for the following reasons:

1. In Ohio, beam pumps are required to force oil into sales lines.
2. The requirements of precision, cleanliness and maintenance of a hydraulic unit were expected to be greatly in excess of those of the beam type unit.
3. Power requirements of the beam unit, operating on a 24-hour basis, would be much less since 60 to 80 percent of the polish rod load could be counterbalanced.

The advantages of the hydraulic unit's long, variable speed stroke were overcome by modification of a standard 34-inch stroke unit. The beam was shifted forward and a large horsehead was installed to give a 48-inch stroke. Installation of a 1948 Ford four-speed transmission between engine and unit gear reducer provided any desired strokes per minute from two to twenty.

<u>Other Equipment Built Special.</u> - In addition to the foregoing pieces of equipment, several items had to be built special and, briefly, were:

1. A casing head made from two flanges, a 2-1/2" nipple and two 1-1/4" outlets.
2. A clamp to connect the pumping wire line to the horsehead bridle.

3. A 1-1/8" heavy steel tube fitted with a stuffing box at one end to carry the wire line through a standard 1-1/8" stuffing box.
4. Three 1" O. D., 18' sinkers with 5/8" box and pins, and a 1" O. D. rope socket.
5. An 18' gas anchor made from 1-1/4" pipe, with a 3/8" skeeter bill attached to the inside wall, connecting the separating chamber to the pump chamber.

Plunger Lift Equipment. - In a previous section of this paper, it was stated that a 1-1/4" piston installation should be designed and tested. A phone call to a Texas manufacturer resulted in 60-day delivery of a complete unit. The piston had no inner valve or moving parts. Also, a new, very simple and positive magnetic motor valve bleed-off mechanism was incorporated into the design.

The next few paragraphs will cover installation and operating results of the equipment just mentioned.

Installation of Equipment

Due to the risk involved, it was decided that installations would be made on a trial basis in existing wells which had casing already cemented on top of or through the sand.

Both pumping and piston equipment were installed at the W. R. Moore lease in section 10, Monroe Township, Coshocton County. This is south of Killbuck about three miles west of Layland.

Pumping Installation. - The pumping equipment was installed in the Moore #6 well. The 5-1/2" casing had been cemented through the Clinton to a total depth of 3,416 feet.

After removal of existing equipment and checking for frac sand, the 2-1/2" casing was set on a hook-wall packer just above the perforations at 3,350 feet. The 2-1/2" casing was supported in the regular 5-1/2" casing head by a set of slips made for this purpose.

Next, the 1-1/4" tubing was run and set with the pump barrel and gas anchor below the pay, the weight being supported by the flange of the homemade casing head.

Pump plunger and sinkers were next run into the well on the 5/8" wire line which was then passed through the hollow polish rod and then clamped securely in the bridle clamp.

After spacing of the bottom-hole pump, the polish rod stuffing box was tightened and the extra 150 feet of wire line was spooled around an old truck rim mounted on top of the pumping unit beam. The purpose of the extra wire line was to provide slack for pulling over the mast of a machine when future servicing would be required.

All well-head connections, checks, etc., were reduced to 1-1/4" size. The hook-up was standard except that what was considered a very important piece of equipment was installed on the pumping tee outlet. This was a spring-loaded pressure controller which purpose is to keep back-pressure on the tubing at all times. The installation was now complete and ready for trial pumping.

Plunger Lift Installation. - The installation of the 1-1/4" piston equipment was made at the Moore #3 well. Casing and tubing was run and set in the same manner as in the pumping installation. The bottom-hole buffer spring was next dropped in the tubing. Lubricator, motor valve and connections were installed. The piston was next placed in the tubing and released to bottom. The installation was ready for trial operation.

Operational Results

The acquisition of materials and equipment for these installations required many weeks with the result that actual test operations were not begun until September.

Pumping Project. - The pumping installation was started on September 8. The bottom-hole pump was spaced at a number of strokes per minute calculated to give a 24-hour production rate which would not pump the well off.

When the well pumped up or began to produce fluid, the pressure controller on the tubing was set at 150 pounds. The purpose of this controller is to keep a solid fluid column in the tubing, thus preventing the well from flowing off which would add to deposition of paraffin in the tubing and cause a changing pressure differential at the bottom-hole pump valves.

Casing pressure was maintained at a constant 125 pounds by a back-pressure regulator on the oil and gas separator outlet.

At this writing, the well has operated a total of 110 days and received only five paraffin solvent treatments. As yet there have been no mechanical failures of the pumping equipment. The only trouble encountered has been the polish-rod-to-wire-line stuffing box which continued to leak after repeated tightenings. However, a new design eliminated the problem.

Before discussion production results, it might be interesting to note that this well had been operating a 2-inch plunger lift and was still in a flowing period when pumping equipment was installed. It being assumed that the well would provide all the problems of pumping a high gas-oil ratio well and also the usual paraffin problems.

Operation was started slowly, and after all equipment was considered reliable, the well was placed on 24-hour operation about October 6.

The equipment has been operated at about 9 S. P. M. and at no time has the well pumped off. As a result, production has increased from about 70 barrels per week to 164. The rate of decline has also improved considerably as shown by graph I.

Pump efficiency has been in the range of 45 to 50 percent.

Mentioned previously, the only trouble encountered was a leaking stuffing box which was replaced, and since that time, the well has operated continuously the last 43 days, being shut down only for engine oil changes.

Plunger Lift Project. - Since installation, the 1-1/4" piston equipment has operated without mechanical difficulty. A casing pressure of 285 psi. has been operating the piston against a line pressure of 150 psi. Results indicate that the equipment would satisfactorily produce a new Clinton well through its flowing period.

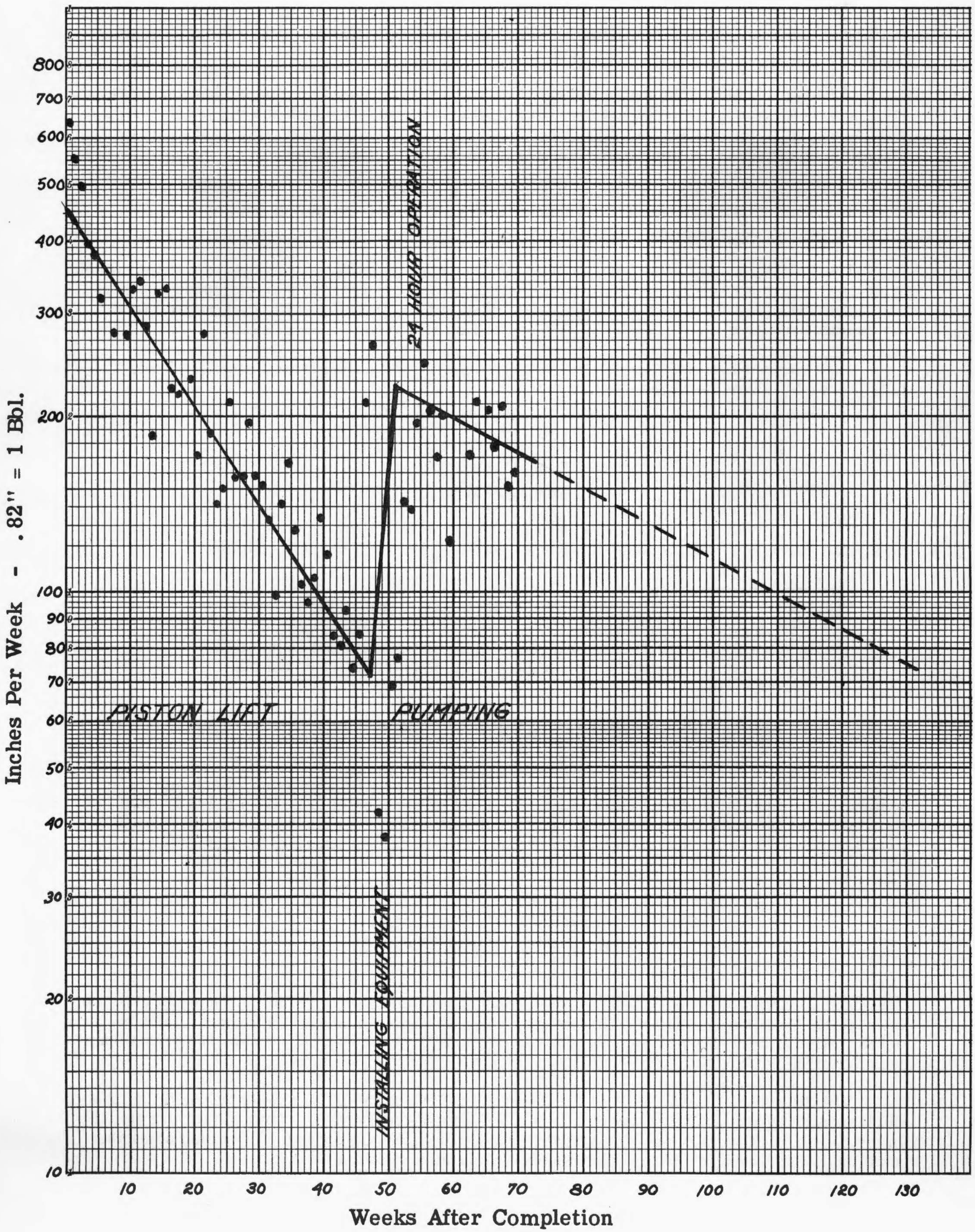
Although these projects have been operated slightly less than six months, it appears that both blowing and pumping production may be handled by slim hole equipment.

If these projects continue to operate satisfactorily, it is planned to drill and permanently complete a well by one of the proposed methods discussed in the following paragraphs.

PROPOSED METHODS OF PERMANENT COMPLETION

In thinking about the ways in which a Clinton well might be completed using slim hole

PRODUCTION RATE OF DECLINE - MOORE # 6



Graph I

equipment, several possibilities come to mind; however, only two methods which are considered to be most practical will be discussed.

In each proposed method, the standard casing program would remain unchanged except that the 5-1/2" casing would be set through the Niagara lime to shut off the big water. This eliminates the time and expense of drilling wet hole to the Clinton. The well would then be drilled-in and tested. At this point, the 2-1/2" would be run and either:

1. Cemented through the sand, perforated and fractured, or
2. Using a Halliburton full-flow packer shoe, the 2-1/2" would be cemented in the top of the sand.

The Halliburton full-flow packer shoe, as shown on page 27, is a pressure-set tool which protects the formation from cementing pressures. After cement has been displaced above the tool's packing element, cementing ports are closed and the interior of the tool pumped from the casing, leaving a full casing I. D. with no drilling required.

After cement has set, the 5-1/2" casing would next be pulled from the well. Table 1 lists the steps of completion in greater detail.

TABLE 1

Proposed Completion Procedure
Slim Hole Method

Step

1. Set 5-1/2" casing through Lime using steel shoe and release coupling up two joints.
2. Drill well in and test.
3. Run 2-1/2" with Halliburton full-flow packer shoe and set in top of Clinton. Use Centralizers.
4. Cement 2-1/2" and pump plug to bottom. Let cement set at least 12 hours. Note: Cement and plug should be displaced with crude oil.
5. Swab and test 2-1/2".
6. Pull 5-1/2" casing.
7. Pull other casing and wash in fire clay as instructed by mine inspector.

These are only proposed completion methods and have not been tried. Each method would require careful planning and execution. They are presented mainly to aid your own thinking about the possibilities of this type completion. Whatever method used, the object is to cut costs. The following example will present an estimate of possible savings.

COST COMPARISON OF REGULAR AND SLIM HOLE COMPLETION

In making a cost comparison between conventional and slim hole completion methods, no attempt has been made to go into fine detail. Only the more important differences have been noted. Similar services and equipment were not considered. Table 2 presents a cost comparison on the above basis.

The difference of estimated costs shown is $5, 390; however, it should be noted that this difference gives consideration to the number of fracture trucks used. Four units were listed in the conventional completion and only two in the slim hole completion, the reason being that additional trucks would not increase injection rates in proportion to cost.

OPERATING DIAGRAM
FULL-FLOW PACKER SHOE

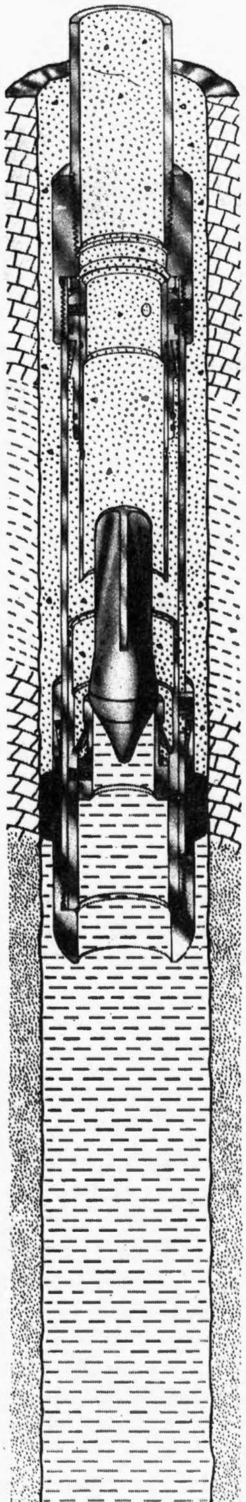


FIG. 1

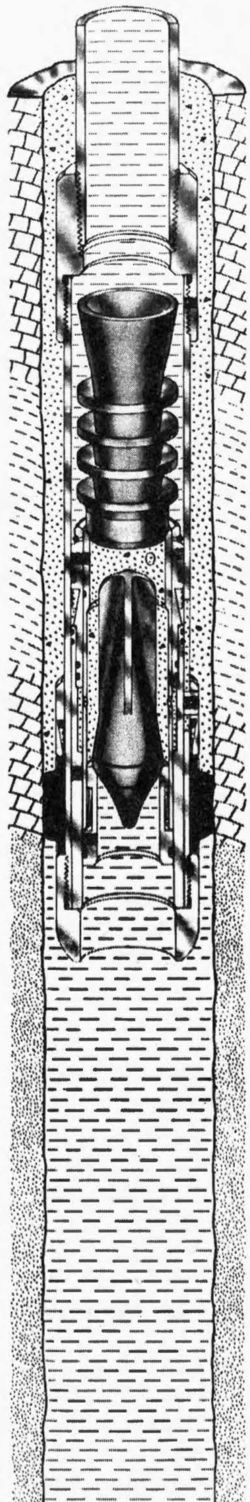


FIG. 2

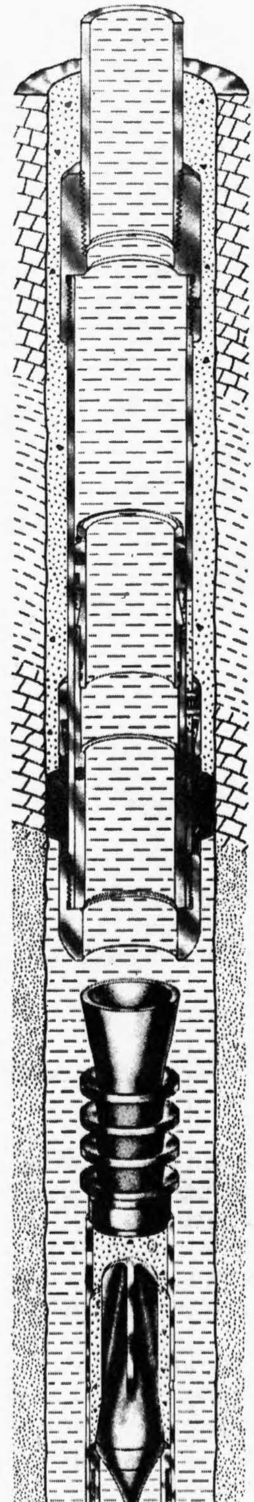


FIG. 3

Graph II

TABLE 2

Cost Comparison of Completion Methods

Conventional		Slim Hole	
Equipment		**Equipment**	
Pumping unit	$ 2,400	Pumping unit.	$ 1,621
2927' - 5-1/2" 15-1/2# at 1.90/ft. .	5,561	2927' - 2-1/2" at .86/ft.	2,517
Float shoe	65	Halliburton packer shoe .	250
Casing head	115	Casing head	25
2927' - 2" Reg. at .66/ft .	1,932	2927' - 1-1/4" Upset at .58/ft	1,698
2927 - 5/8" Rods at .3115/ft	911	3027' - wire line at 23.5/ft.	722
Bottom-hole pump	190	Bottom-hole pump . . .	150
		Centralizers - 2 ea. . .	75
Drilling		**Drilling**	
2950' at 2.55/ft.	7,522	2950' at 2.35/ft.	6,932
		Pull, 5-1/2".	120
Fracture		**Fracture**	
4 - Trucks at $427 . . .	1,708	2 - Trucks at $427. . .	854
Other		**Other**	
		Extra trucking	50
Total	$20,404	Total	$15,014
Difference	$ 5,390		

Depending on each producer's present cost of completion, savings by this method would probably range from 15 to 20 percent. While these savings may not seem significant to some, the total cumulative saving becomes quite large when considering an active drilling program.

OTHER SAVINGS AND ADVANTAGES

In addition to the savings already noted in the previous example, several other advantages and savings might be mentioned. For example, with wells on slow 24-hour operation, the size and capacity of oil and gas separators could be greatly reduced. Also, 24-hour operation gives better control of production since strokes per minute (S. P. M.), casing press, and tubing press are reported to the production department and pumpers are not permitted to change any settings without permission from the production foreman.

Since installation of pumping equipment in the Moore #6 well, in which a working barrel arrangement was used, a small-bore insert pump is available. These pumps are of the liner type and, to date, we have run many 3/4" and 1" bore pumps with very substantial increases in production. These pumps are operating 24 hours a day at very few S. P. M. Auxiliary transmissions provide the necessary reduction. Also, all facilities for plating, grinding, and honing worn pump plungers and liners are available and promise considerable savings in pump repairs.

Another advantage of 24-hour operation of very small bore pumps is the reduction of polish rod loads and horsepower requirements. Smaller units and engines may be used. However, the additional torque necessary to operate a Buckeye beam pump requires that the pumping unit gear reducer be one rating higher than necessary for just pumping the well. Calculated torques indicate that a 16,000 in.-lb. reducer would otherwise be ample. We are currently cooperating with a manufacturer on the development of a low torque 48-inch stroke unit.

It was mentioned earlier that slack wire line was provided to pull over a service machine mast. The wire line in the Moore #6 well has been pulled only once, and total pulling time was not more than 30 minutes. This is a considerable savings in machine time and labor. Incidentally, when the wire line was inspected after 55 days operation, there was no evidence of wear.

In view of the apparent advantages of the slim-hole completion, there are also some problems and disadvantages to consider.

PROBLEMS AND DISADVANTAGES

When comparing costs earlier, it was mentioned that only two fracture trucks were included in the slim hole completion and that additional trucks would not add sufficiently to injection rates. A conservative estimate by service company engineers of the maximum economical injection rate possible through 3,000 feet of 2-1/2" tubing is fifteen barrels per minute. In a period when injection rates have been increasing rapidly, this may be considered by some as a cancelling factor to the entire method of completion. However, slim hole equipment is on the increase in other areas of the southwest and this factor will have to be evaluated by the individual producer.

Servicing at first might be considered a serious drawback to slim hole equipment. In the introduction of this paper, it was mentioned that tools and methods were available. One recent servicing development, now operating on a commercial basis, is described on page B-40 of the January 1959 issue of Petroleum Engineer. The method uses a combination of high velocity air, detergents, and foaming agents to clean out 4,000-foot wells in north Texas. Average actual clean-out time is only six hours. This method might be applied to Ohio wells also.

Although problems and disadvantages exist to a degree, they are not considered to outweigh the advantages and possible savings of the slim hole completion.

CONCLUSION

Slim hole completion equipment and methods are being developed rapidly by an oil industry which is seeking to reduce costs wherever possible. The method, if further tests prove successful, may help the Ohio producer reduce present completion costs by 15 to 20 percent. In the example given, savings were estimated at $5,000 per well.

Each producer should ask himself the question, "What do we do next if completion costs continue to rise with no change in crude prices?" It becomes clear that we must accelerate our efforts toward better and cheaper methods of operation.

The two projects discussed in this paper are successfully producing through 2-1/2" casing strings and 1-1/4" tubing--one pumping, the other flowing by piston lift. While these projects have operated only a short time, they are providing experience on which to base a decision to permanently complete a well by the proposed method.

The main purpose of this paper has been to:

1. Emphasize the importance of beginning "now" to consider any new methods of cutting costs.
2. Remind the Ohio producer that there are possible ways to cut costs.
3. Provide a few ideas, facts, and results which may be helpful in your efforts to attain that goal.

REPRESSURING - WITH GAS AND WATER

by

Graham Robb

A few months after drilling was completed on our 160-acre Jacob Kreager lease, the production started decreasing on the usual decline curve for the Clinton sand. In an effort to slow this decline and therefore recover additional oil, it was decided to attempt recycling of the produced gas.

This lease is located in Hopewell Township, Licking County, and is owned by Oxford Oil Company, Natol Corporation, Mrs. Ruth B. Nicholas, and Mr. Donald P. Sanders. Development of the lease began in late 1956 and in addition to the old number one well which was drilled in 1937, eight new wells were drilled and fractured in the Clinton sand. The Clinton sand in this area is found at approximately 3,100 feet, and on this lease the net pay sand is fairly uniform. Unfortunately, there were no cores taken nor were there any logs run on the wells, therefore all information on sand characteristics must be obtained from sand samples taken while drilling in.

The wells on completion after fracture had a higher than average initial production of oil and gas and the average gas-oil ratio for the first month's production was 0.105.

The gross production attributable to the working interest from time of completion until recycling started amounted to 76,337 bbls. During this time the gas-oil ratio had increased from 0.105 to 1.045. Since we felt that the best results from the recycling program would be realized by starting as soon as possible, a program was selected and placed into operation early in 1957.

The selection of the proper size compressor was a problem because of the unknowns involved. It was finally determined that a capacity of 500 mcf per day at a discharge pressure of 1,000 psi would be adequate for this lease with excess capacity for program expansion. A Gardner-Denver Unitized $9\frac{1}{4}$" x $4\frac{1}{4}$" x 11" Tandem Compressor equipped with automatic safety shut-down controls was selected.

This unit has proved satisfactory and with the exception of routine maintenance has given us practically trouble-free operation.

A flowing well in the center of the 160-acre lease was converted to an injection well by simply connecting the gas injection line to both the casing and tubing and gas recycling was then started in July 1957. The injection pressure and the injection rate were initially 525 psi and 900 mcf per month, respectively. They were slowly built up over a period of four months to 740 psi and 3,800 mcf. This may be observed on the accompanying graph. The total gas recycled through December 1958 was 63,712 mcf.

The production decline curve shows graphically the results of the gas recycling. The additional oil production, resulting from the program through December 1958 amounts to 6,000 bbl and the estimated total for the life of the program, 49,000 bbl. This is an increase of 35 percent over the amount of oil recoverable by the standard production methods.

The total cost of the compressor, including installation, was about $30,000 and since the program has expanded to include other leases, only 50 percent of this $30,000 is chargeable to the Kreager lease. The operating and maintenance costs for the life of the program will amount to approximately $15,000, bringing the entire cost of the project to approximately $30,000. Since the expected return for this investment is $117,000, a profit of $87,000

* Mr. Robb is associated with the Oxford Oil Company and Mr. Wood with the Quaker State Oil & Refining Company.

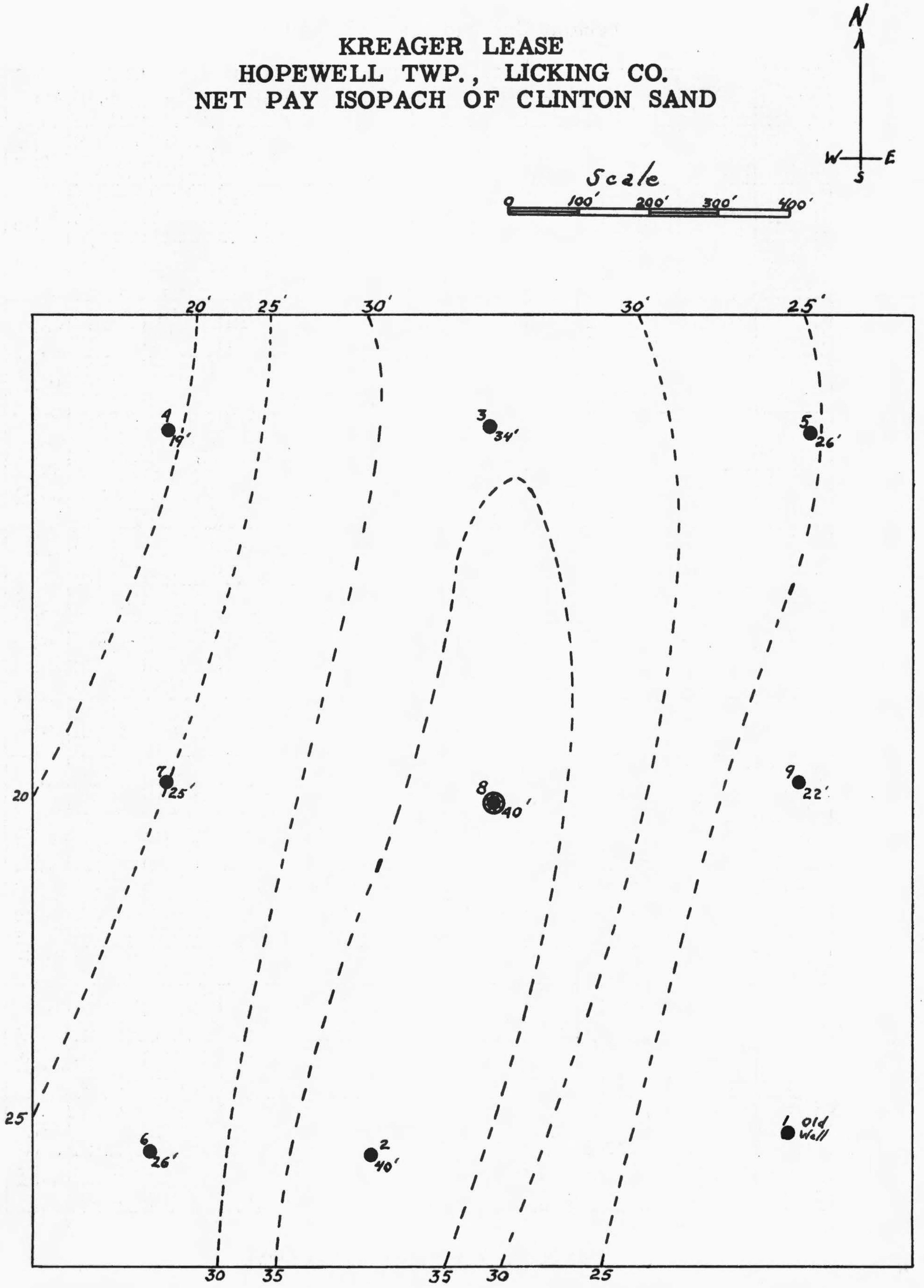
should be realized. The graph shows the time it will take to recover the original investment and when the project will begin to show a profit.

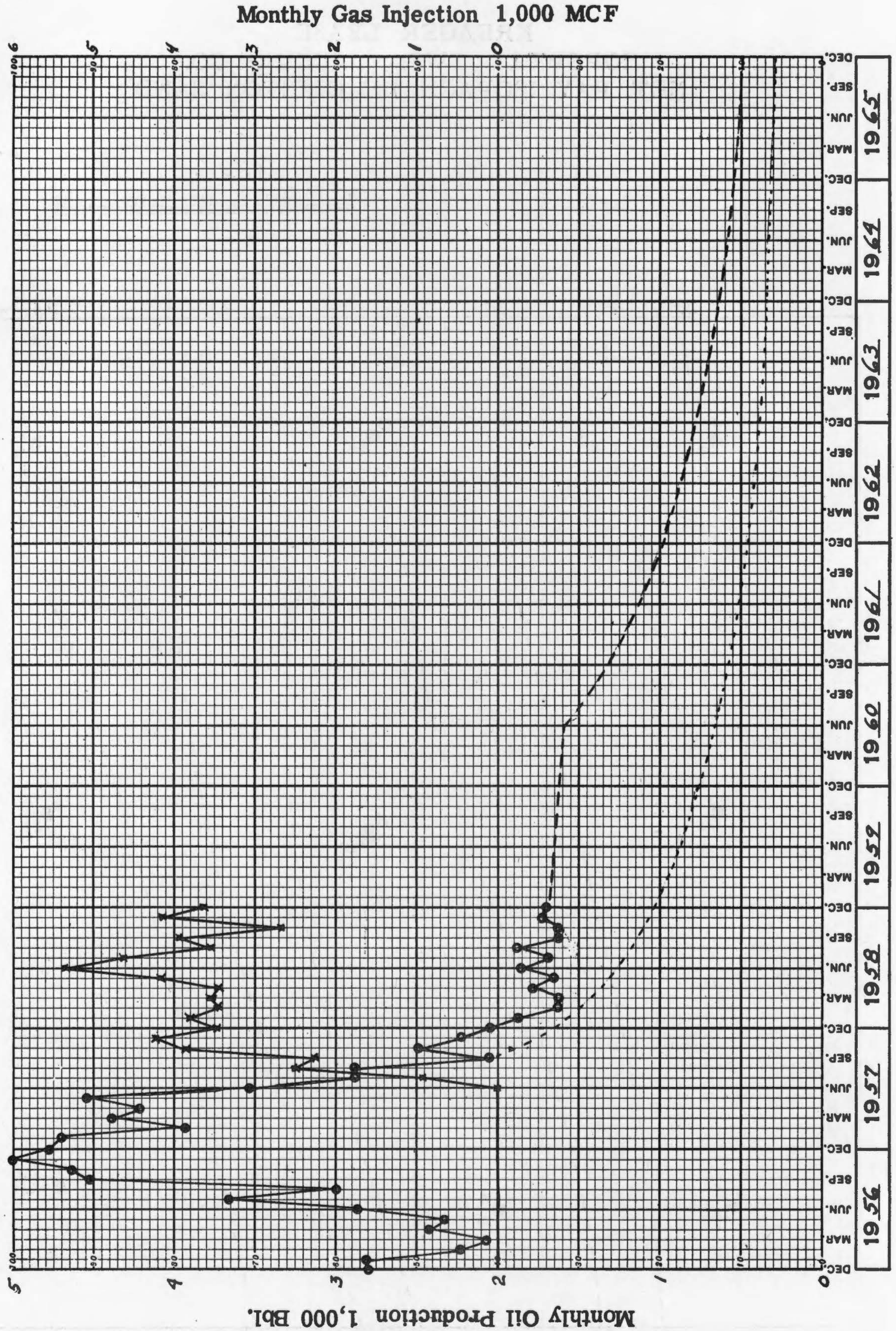
The toughest problem we have had has been the removal of the moisture from the compressed gas to prevent hydrate formation in the surface lines and down the hole. Initially, drips were installed in the low places in the line and when this failed, we attempted to cool the gas and remove the moisture with one large drip in conjunction with an Anderson purifier. However, the gas was either too hot and would not drop the moisture, or it was too cold and would freeze in the line before it reached the purifier. Last month we purchased and installed a small Parkersburg Glycol Dehydration Unit, which should stop hydrate formation; however, at this time we do not have the performance figure on this equipment.

The program has been expanded during the past year and recycling is now being carried out on the adjoining leases to the north and the east. The present recycling rate into all three leases is 10,000 mcf per month.

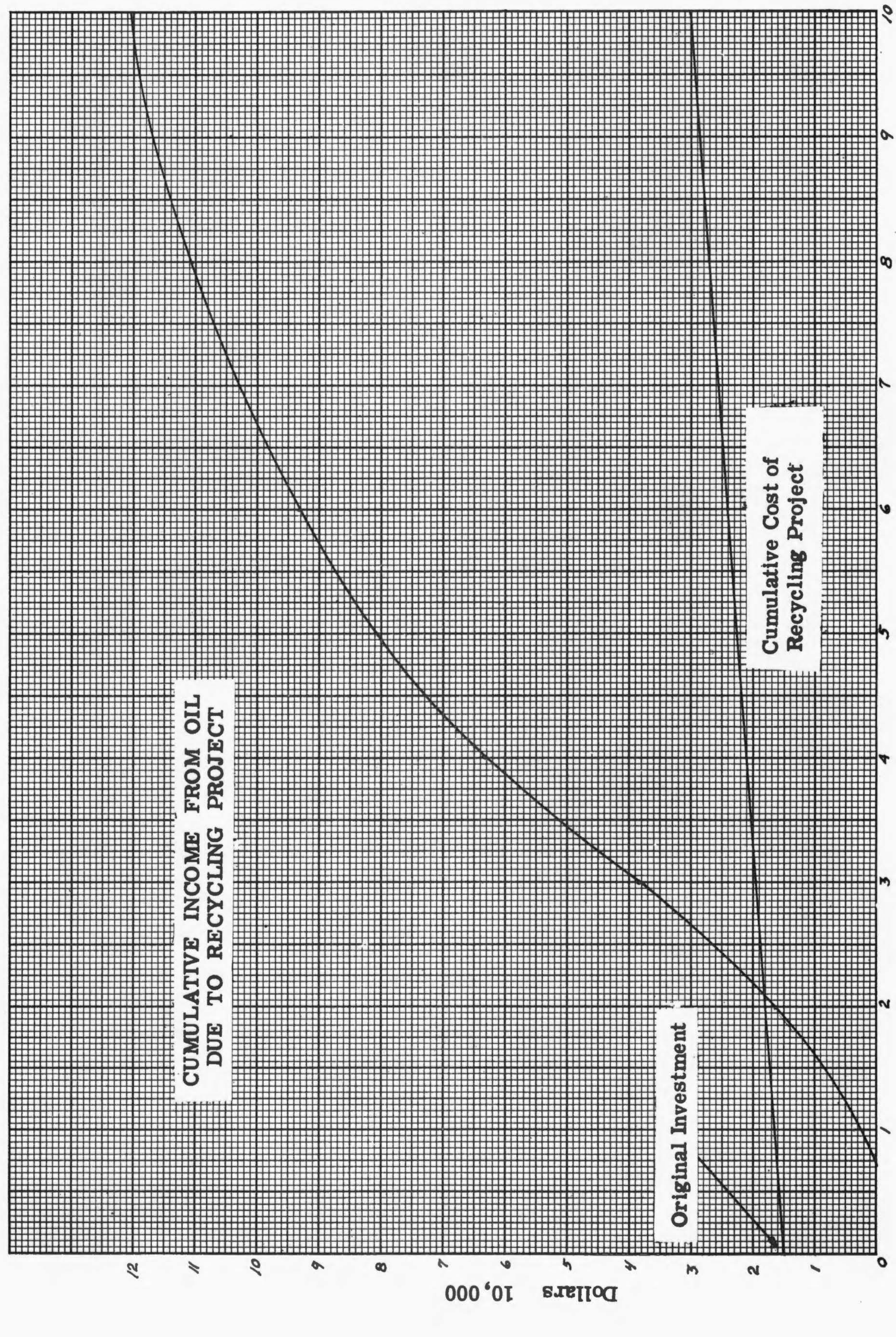
We estimate the primary oil recovery with normal pressure depletion amounts to about 30 percent of the total oil in place. The recycling program we are carrying out will increase the recovery to 40 percent of total oil. This is still a relatively low percentage but it is hoped that someday we will be able to increase the ultimate recovery by some form of secondary recovery.

KREAGER LEASE
HOPEWELL TWP., LICKING CO.
NET PAY ISOPACH OF CLINTON SAND





Monthly Gas Injection 1,000 MCF
Monthly Oil Production 1,000 Bbl.
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
DEC.
MAR.
JUN.
SEP.


CUMULATIVE INCOME FROM OIL
DUE TO RECYCLING PROJECT
Cumulative Cost of
Recycling Project
Original Investment
Dollars 10,000
0
1
2
3
4
5
6
7
8
9
10
11
12